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VARIATIONS IN THE CARIES SUSCEPTIBILITY OF CHILDREN'S TEETH

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INTRODUCTION

CONSIDERABLE variation in susceptibility to dental decay occurs between teeth in different regions of the mouth and between various surfaces of the same tooth. The first type of variation has been studied by Knutson, Klein and Palmer ('38), and the second by Hyatt ('27, '30), Leigh ('24) and Walsh and Smart ('48). This paper presents the results of a further investigation of such differences in susceptibility, in which smooth and pitted surfaces have been examined separately since a previous study had suggested that these may differ in etiology (Grainger and Reid, '54).

The data were obtained by examining the permanent teeth of 1144 school children, ages 6 to 17 years inclusive, in the town of Burlington, Ontario. Examinations were done by the district dental health officer

with mouth mirror and explorer according to a recording system already reported (Grainger and Reid, '54). The surfaces of the teeth were divided into areas which appeared to act as discrete and independent origins of dental caries. These were basically the mesial, distal, lingual, labial or buccal, and occlusal surfaces; the incisal edges were ignored. The buccal surfaces of the lower molars, the lingual surfaces of the upper molars, and the lingual surfaces of the upper incisors were further sub-divided into the smooth area near the gingiva, and the pitted or fissured region farther from the gum. The presence or absence of each permanent tooth, and the caries-affected surfaces were recorded for each child. The proportions of the specific tooth surfaces decayed of those examined were then calculated for each age, combining the two sides of the mouth. The number of missing teeth was not great enough to influence perceptibly the results obtained.

The following section outlines the statistical analysis used in the study.

STATISTICAL ANALYSIS

It seems likely that caries-producing attacks tend to occur randomly in time. If, then, the attack rate remains constant, while differences between individuals are small relative to chance variation, the proportion of surfaces free from decay, at age t, may be approximately written as

$$P_t = e^{-b(t-a)},$$

where b is a measure of the attack rate and a is the age at which exposure begins. b, in fact, could be interpreted as the number of caries-producing attacks per year. This expression implies that

$$-\log_e P_t = k + bt;$$

that is, the natural logarithm of the proportion free of decay is linearly related to age, the slope of the straight line being the caries attack rate.

The requirements for this simple relationship may be met by individual tooth surfaces for children of the ages studied. Conditions predisposing to cavitation probably do not change greatly in the mouth, nor in the local environment of the surface, over this period. While the total number of caries lesions accumulated will reflect individual variation in susceptibility, this certainly would be of much less importance for the single surface. Variation in the age of eruption of teeth would tend, naturally, to cause deviation from the above pattern. However, assuming that the distribution of eruption times is a normal distribution

and the value of b is small, it may be shown that the simple relationship should hold from about two to three years after the average age of eruption, most individuals having the particular tooth involved by this time.

The application of this formula to the data for the distal surface of

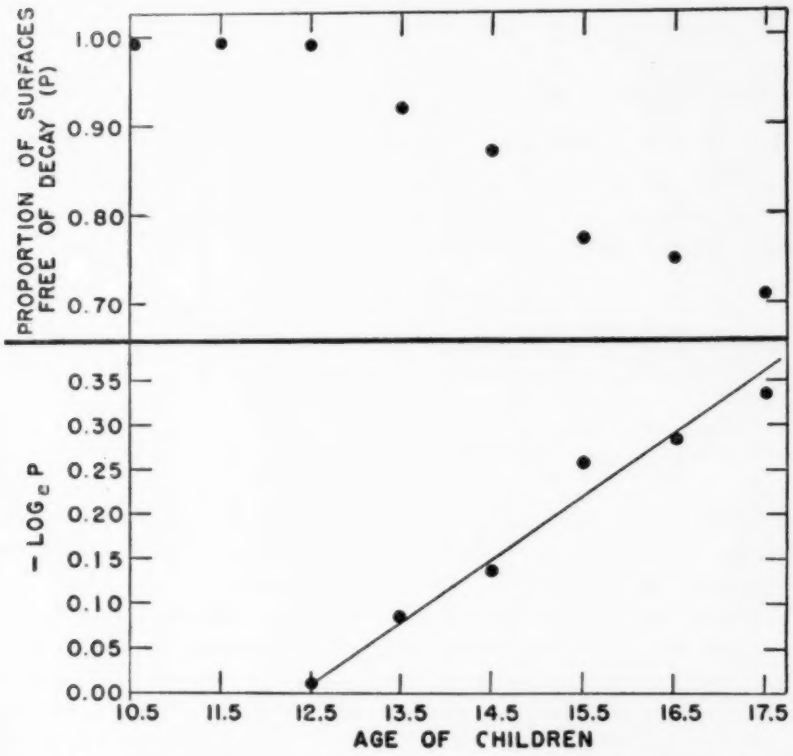

FIG. 1. THE ACCUMULATION OF DENTAL CARIES ON THE DISTAL SURFACE OF THE MAXILLARY FIRST PREMOLAR.

maxillary first premolar is illustrated in figure 1. In the upper part of the figure the proportions of surfaces free of decay are plotted from age 10 to age 17, the average age of eruption being 10.4 years. The proportion free of decay declines steadily from 12 years. In the lower part of the figure the negative logarithms of the proportions are plotted against time, giving a reasonably straight line with slope of about 0.07,

The surface is accumulating cavities at an average rate of 0.07 cavities per year.

This constant may be estimated arithmetically in a number of ways. Since the point of origin cannot be readily specified, it is probably best to estimate both a and b. By the method of least squares,

$$b = \frac{\Sigma W(y-\bar{y})(t-\bar{t})}{\Sigma W(t-\bar{t})^2},$$

where $y = -\log_e P$, and $W = \frac{N\hat{P}}{(1-\hat{P})}$. $\hat{P}$ is the "true" proportion of decayed surfaces and N the number of surfaces examined at any age. Since $\hat{P}$ is not known these calculations must use weights estimated from a graphical fit of the data or a previous cycle of iteration. In addition, it is possible to evaluate

$$\chi^2 = \Sigma W(y-\bar{y})^2,$$

to serve as a measure of goodness of fit of the relationship. If the fit is satisfactory, the standard error of b is given by

$$s_b = \frac{1}{\sqrt{\Sigma W(t-\bar{t})^2}}$$

For distal surface of maxillary first premolar the method yields the estimates: $b = 0.071 \pm 0.006$; $\chi^2 = 1.52$. The value of χ^2 is based upon 4 degrees of freedom, and is clearly not significant.

It is assumed in these calculations that the individual observations are independent of one another. Since two surfaces from each individual are included in each proportion this is not strictly correct. However, on smooth surfaces at least, the correlation between the two sides of the mouth is small and would not greatly affect the validity of the procedure.

RESULTS

In most cases it was found possible to estimate satisfactorily the caries attack rates for smooth surfaces by the method outlined, though on some of the surfaces there was so little decay that no attempt was made to do so. These rates are given in table 1. In general, the susceptibility of the teeth increases posteriorly in the mouth. An additional slight increase was observed in three mesial surfaces of maxillary teeth, extending from the canine to the first incisor. Adjacent pairs

TABLE 1

Caries attack rates of specific smooth tooth surfaces

	Maxilla			Mandible			
Tooth	Labial or Buccal	Mesial	Distal	Labial or Buccal	Mesial	Distal	Lingual
1st Incisor	—*	.032 ± .003	.026 ± .004	—	.002 ± .001	.003 ± .001	—
2nd Incisor	—	.023 ± .003	.007 ± .002	—	.003 ± .001	.001 ± .001	—
Canine	—	.005 ± .003	.011 ± .003	—	—	—	—
1st Premolar	—	.020 ± .003	.071 ± .006	—	.004 ± .002	.030 ± .004	—
2nd Premolar	—	.056 ± .006	.068 ± .007	—	.027 ± .005	.037 ± .006	—
1st Molar**	.008 ± .002	.052 ± .003	.005 ± .002 .062 ± .012	.007 ± .001	.054 ± .004	.013 ± .003 .081 ± .010	.007 ± .002
2nd Molar	.026 ± .006	.017 ± .006	.010 ± .004	.017 ± .003	.035 ± .011	.011 ± .005	—

* A dash indicates that either no caries occured, or so small a number that the caries attack rate could not be determined. This was the case for all upper lingual smooth surfaces.

** The second rate for distal surfaces of the first molar refers to the period following the eruption of the second molar.

of interproximal tooth surfaces are, in many instances, quite similar in susceptibility. The buccal and labial surfaces on the whole have higher rates than the lingual, while the interproximal have much higher rates than any of these.

The distal surfaces of the first molar present an interesting variation on the general pattern. The negative logarithms of the proportions free of decay for this surface on the mandibular first molar are plotted against

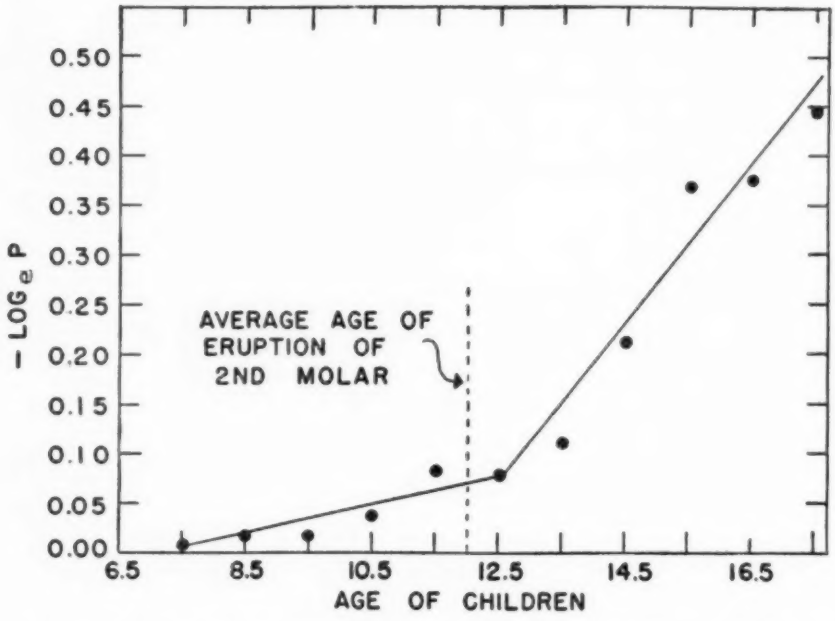

FIG. 2. THE ACCUMULATION OF DENTAL CARIES ON THE DISTAL SURFACE OF THE MANDIBULAR FIRST MOLAR.

age in figure 2. The trend of these figures suggests that a change occurred in the average rate of accumulation of cavities about age 13, a year or so after the average age of eruption of the second molar. For this reason two straight lines were fitted, the one to age 12 inclusive and the other from age 12 to age 17. The slopes of these are 0.013 cavities per year and 0.081 cavities per year, respectively. The same procedure was needed for the upper first molar.

The determination of the values of b was difficult for some of the pitted surfaces. The reason for this is evident from the decay pattern

shown in figure 3 for the occlusal surface of lower first molar, which is fairly typical. Decay on this surface seems to have taken place from the first appearance of the teeth in the mouth so that the proportion free of decay declines very rapidly. However, after this initial fall the proportion remains relatively constant, as if a certain proportion of individuals are resistant to decay on this surface. There is a subsequent slow increase in the proportions, but this may be due to drilling down

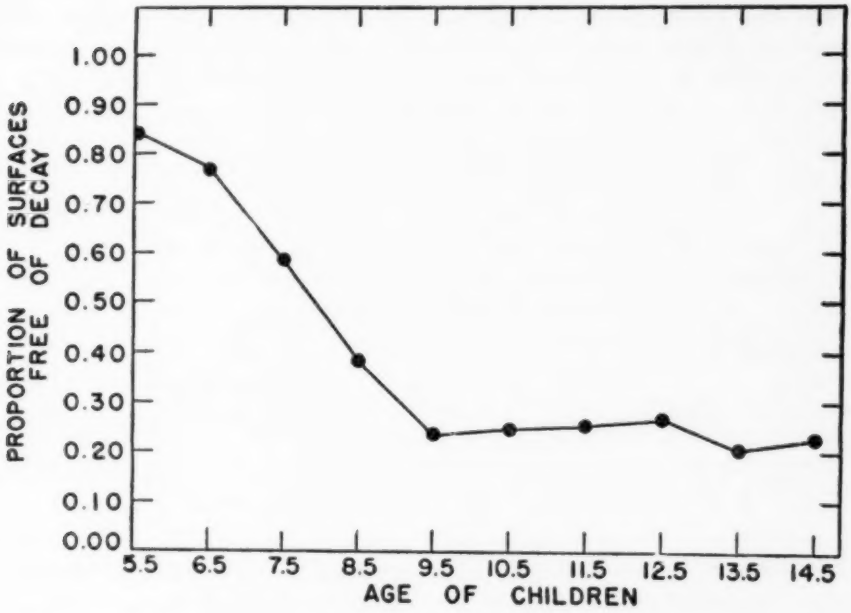

FIG. 3. REDUCTION IN THE PROPORTION OF SURFACES FREE OF DECAY ON THE OCCLUSAL SURFACE OF THE MANDIBULAR FIRST MOLAR.

through the intact occlusal surface in order to gain access to a carious interproximal surface. On this assumption the proportion free of decay can be corrected so that it is based only on the group which shows decay over the initial period. In this case about 24% might be assumed caries resistant. A straight line could then be fitted to the points available, those for the years 6. 7 and 8. The value of b is 0.58. This procedure is not satisfactory since only a few points are available for the estimation of b, including one in the neighborhood of the average age of eruption. In addition considerable correlation probably exists between the occur-

rence of cavities on this surface in opposite sides of the mouth. However, the procedure does provide an estimate comparable to those for the smooth surfaces.

All of the pitted surfaces appeared to reach a maximum proportion decayed except the occlusals of the premolars, which may indicate that these should be considered as smooth surfaces. Where necessary the pitted surfaces were then adjusted on the basis of the stable period, and decay rates estimated. These are given in table 2. Standard errors are also tabulated, though these may considerably underestimate the correct values. As a group, the pitted surfaces are much more suscep-

TABLE 2

Caries Attack Rates of Specific Pitted or Fissured Tooth Surfaces

Tooth	Maxilla		Mandible	
	Occlusal	Lingual	Occlusal	Buccal
1st Incisor		—		
2nd Incisor		.29 ± .08 (9%)*		
1st Premolar	.040 ± .006		.008 ± .003	
2nd Premolar	.080 ± .008		.047 ± .008	
1st Molar	.55 ± .04 (73%)	.16 ± .02 (24%)	.58 ± .08 (76%)	.30 ± .04 (40%)
2nd Molar	.56 ± .07 (76%)	.44 ± .21 (9%)	.94 ± .21 (87%)	.71 ± .24 (20%)

* The value in parentheses is the estimated maximum percentage of surfaces susceptible, used in the adjustment of the proportion of surfaces decayed.

tible than the smooth surfaces; this is notable for the buccal or lingual pitted surfaces as compared to the smooth surfaces of the same tooth. They are somewhat more susceptible in the back of the mouth, though the difference is not nearly as marked as for the smooth surfaces.

DISCUSSION

The greatest contrast in the attack rates shown is between those for smooth surfaces and those for pitted surfaces. The presence of a deep pit or fissure on the surface of a tooth seems to result in a cavity developing soon after tooth eruption. This occurs even though the pits are located in regions where the caries producing influences are weak. In a certain percentage of individuals decay does not occur either because the pits are not formed in the development of the tooth, or because the

mouth is inherently immune. This percentage is small for the occlusal surfaces, but relatively large for some of the other pitted surfaces.

The pattern of decay on the smooth tooth surfaces seems, on the other hand, to reflect environmental variations in the mouth. The rates for interproximal surfaces are high and tend to be similar for adjacent surfaces, reflecting the local conditions of the space between the teeth. The relatively low rate of decay on the mesial surface of the maxillary second molar is an exception to the general pattern. The increased rate of decay of the distal surfaces of both maxillary and mandibular first molars upon the eruption of the second molar further suggests that the higher rates for interproximal surfaces are associated with confinement of the tooth surface. The lowest attack rates are found where the saliva is abundant near the openings of the salivary ducts, and where the action of the lips and tongue, and the masticating action of the teeth, prevent stagnation.

It is of interest to compare these data with two sets from other localities. The first were obtained by an expedition to the mountains of Greece, where villagers were living on a rather restricted diet thought to be low in minerals (Moyers and Johns, manuscript). The second set were obtained from Aylmer, Ontario, an area where the natural water supply has contained 1.2 p.p.m. of fluoride for at least 18 years (Coburn and Knipe, '53). The attack rates for the surfaces of the anterior maxillary teeth, and the mandibular first molars in these areas, together with estimates obtained in the present study, are given in table 3. These teeth were selected since they are representative of pitted and smooth surface caries on both the anterior and posterior teeth. Neither the Burlington nor the Greek water supplies contained significant amounts of fluorides.

The caries attack rates for the Greek area are quite similar to those of Burlington, Ontario. Moreover, the Greek data confirm the observation that the proportion of pitted surfaces decayed reaches a maximum very shortly after the teeth erupt. There was, however, no subsequent increase on the occlusal surfaces of the molars, probably because none of these children had dental treatment. The natural fluoride area shows an interesting departure from the pattern of decay observed in the other two areas. While the pitted surface attack rates appeared to be about the same as elsewhere, the smooth surface rates were very much lower in both the anterior and the posterior teeth. Reports on fluoride studies have frequently emphasized the protection given to the anterior teeth,

and have suggested that these teeth received additional benefit because they were bathed in water in the act of drinking. However, it seems that the smooth surfaces of the posterior region are just as well protected as those of the anterior region; the relatively lower protection afforded to the posterior teeth is due to the presence of a greater number of pits and fissures on these teeth.

TABLE 3

Comparison of Caries Attack Rates for Certain Tooth Surfaces, in three Geographical Areas

Tooth Surface	Source of Data: Burlington, Ontario	Greece	Aylmer, Ontario
Smooth:			
Maxillary Anterior			
Mesial, 1st incisor	.032 ± .003	.020 ± .004	.008 ± .003
Distal, 1st incisor	.026 ± .004	.020 ± .003	.007 ± .002
Mesial, 2nd incisor	.023 ± .003	.020 ± .004	.012 ± .005
Mandibular Posterior			
Mesial, 1st molar	.054 ± .004	.053 ± .006	.017 ± .003
Distal, 1st molar **	.013 ± .003 .081 ± .010	.014 ± .004 .030 ± .020	— .006 ± .009
Pitted:			
Maxillary Anterior			
Lingual pit, 2nd incisor	.29 ± .08 (9%)	(4%)*	.21 ± .03 (3%)
Mandibular Posterior			
Occlusal, 1st molar	.58 ± .08 (76%)	(52%)*	.75 ± .06 (54%)
Buccal pit, 1st molar	.30 ± .04 (40%)	.22 ± .09 (27%)	.48 ± .07 (21%)

* The carries attack rates could not be estimated for these surfaces.

** The second rate refers to the period following the eruption of the second molar.

The proportions of susceptible pitted surfaces are similar in the Greek and fluoride areas, being less than the corresponding values found in Burlington. The differences may represent real differences in susceptibility in these areas, though they may be due in part to differences among examiners or in the level of treatment. In the latter case it would imply that a proportion of the "carious" pits which occur on these surfaces are not progressive in nature.

SUMMARY

The rate of caries accumulation on specific permanent tooth surfaces of school children in Ontario was estimated from the slope of the line relating the negative logarithm of the proportion of surfaces free of decay to the age of the children. Caries attack rates for smooth surfaces could be satisfactorily estimated by this procedure; they seemed on the whole to reflect environmental conditions in the mouth. Rates for pitted surfaces were more difficult to determine because of the tendency of these surfaces to decay rapidly or not at all.

These rates were compared with those for Greek children, and children living in a fluoride endemic area. On pitted surfaces, the rates tended to be similar in all three areas, though differences occurred in the proportion of susceptible teeth. On smooth surfaces, while the rates for this study and for the Greek data were similar, those for the fluoride area were considerably less on both anterior and posterior teeth.

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THE SEXUAL DIAGNOSIS OF ISOLATED BONES OF THE SKELETON

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INTRODUCTION

TO ASCERTAIN the sex of human remains is of great importance both in historical anthropology when studying the typology of a group of people and in certain cases of medico-legal interest.

When the whole skeleton is available, in most cases the skull permits the diagnosis of sex, but when the skull is missing and only isolated bones or parts of bones are available recourse must be taken to the most important sexual differences of such bones to try to effect a diagnosis. Sometimes, even when the skull is available, certain bones of the skeleton permit a diagnosis the correctness of which, if based on the skull alone, would be very doubtful.

In this paper we are interested in examining the probabilities of rendering an accurate diagnosis of the sex of an individual based solely on certain isolated bones of the skeleton independently from the sexual dimorphism of the skull.

The most important sexual differences which a somatoscopic examination shows among various bones have been known for a long time and they are very useful in diagnosing the sex. It is obvious, however, that subjective opinions may influence the diagnosis. If the doubtful cases were few, this would not be a problem, but unfortunately such is not the case.

If quantitative traits of great sexual dimorphism are used, it is evident that all subjectivism disappears. Thus, if a sufficient number of remains of known sex are available, two statistical series can be prepared, one for each sex, and for the diagnosis the midpoint between

the averages of the two series could be taken as a basis. Values higher than $\frac{M\,\delta + M\,\varphi}{2}$ could be regarded as belonging to one of the sexes, and values lower than that to the other sex. However, as polygons of variability for each sex overlap, it is evident that errors in the diagnosis will be made; the errors will be greater as the overlap between the polygons is greater. On the other hand, if several quantitative traits of sexual dimorphism are known, a discriminant function between them may be calculated, which if applied to the specimens to be studied gives two discriminant series, one for each sex. In general the overlap in variability will be lower and therefore the probability of incurring an error in the diagnosis also will be lower.

For the calculation of discriminant functions it is necessary to have available bones the sex of which is positively known, instead of merely diagnosed. Only in this way will the averages, variability and overlap obtained be really representative of the population being investigated. For the purpose of this paper we have used data relative to individuals of known sex included in the publications of the Anthropological Institute of Coimbra University entitled "Contribuçoes para o Estudo da Antropologia Portuguesa" (Serra, '41, and Tamagnini and Vieira de Campos, '49).

On the other hand, it is realized that the employment of discriminant functions in a specific case will be appropriate only when the specimen under study belongs to the population which has been taken as a basis for the calculation of the function, or to some other population of very similar sexual dimorphism. In fact, this limitation applies with equal force to all methods that may be employed.

If we bear in mind the percentages of probable correctness in sexual diagnosing which according to Hrdlička ('47), may be obtained by adding the skull to other parts of the skeleton, it is believed that the percentages obtained in this paper with isolated bones alone are worthy of consideration. Furthermore, it is not claimed that the calculated functions are final; they only represent a basis for examination which it would be of interest to apply to other measurements of the same bones as well as to other bones of the skeleton. Discriminant functions for the femur and the sternum are calculated.

DISCRIMINATION IN THE FEMUR

The bone material studied for use in the present paper belongs to the "Ferraz de Macedo" collection of the Bocage Museum in the Faculty of Sciences of the University of Lisbon. It is a collection of "identified skeletons" of Portuguese people of about the end of the nineteenth century. Individual data regarding the femora of this series are included in a publication by Tamagnini and Vieira de Campos ('49).

As is well known, the femora, like all other long bones, are usually wider and longer in males than in females. Also, those of the males have more definite muscular insertion reliefs than those of females, but the more important sexual differences are found in the articular extremities which, in the case of males, are generally and relatively greater than in the case of females. Thus, a femur with a large head cannot be a female's, while one with a very small head cannot belong to a male. In intermediate sizes, however, in many instances, the diagnosis is not so easy, if not impossible. This is specifically so in the zone of overlap of the variability polygons of the sexes.

The metrical traits given in the publication by Tamagnini and Vieira de Campos referred to above, which we use here, are: 1) length in standing position; 2) diameter of the head; 3) minimum transverse diameter of the diaphysis; and 4) width of the lower articulation. The techniques of measurement are described in the above-mentioned publication. In the following discussion the traits are numbered 1, 2, 3 and 4, and with them we have calculated, for right and left femora, discriminant functions following the procedure of Fisher ('36 and '49).

In table 1 are shown the respective averages and differences obtained for each trait, and in table 2 are given the *sum of the squares* of the deviation of each variant with respect to the average value (S_{11}, S_{22}, S_{33} and S_{44}), and the *sum of the products* of the deviations of each variant with respect to the average values of each pair of traits (S_{12}, S_{13}, S_{14}, S_{23}, S_{24} and S_{34}).

With the sum of the squares, the sum of the products, and the differences between averages, the following system of equations are propounded:

$$\left.\begin{aligned} S_{11}b_1 + S_{12}b_2 + S_{13}b_3 + S_{14}b_4 &= d_1 \\ S_{21}b_1 + S_{22}b_2 + S_{23}b_3 + S_{24}b_4 &= d_2 \\ S_{31}b_1 + S_{32}b_2 + S_{33}b_3 + S_{34}b_4 &= d_3 \\ S_{41}b_1 + S_{42}b_2 + S_{43}b_3 + S_{44}b_4 &= d_4 \end{aligned}\right\}$$

in which the results of b_1, b_2, b_3 and b_4 are proportional to the coefficients of the discriminant linear function:

$$X = b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$

and substituting in that system of equations the values given in tables

TABLE 1

Averages and Differences for Each Trait

	Right Femora			Left Femora		
	Males	Females	Difference	Males	Females	Difference
1. Length in standing position	443.95	397.42	46.53	444.69	398.03	46.66
2. Diameter of the head	46.11	39.94	6.17	46.06	39.87	6.19
3. Minimum transverse diameter of the diaphysis	26.13	23.55	2.58	26.44	23.79	2.65
4. Width of the lower articulation	75.60	65.03	10.57	75.44	64.95	10.49

TABLE 2

Sum of the Squares and Sum of the Products

	Right Femora			Left Femora		
	Males	Females	Totals	Males	Females	Totals
S_{11}	26366.84	27215.06	53581.90	27961.04	26903.94	54864.98
S_{22}	314.25	235.78	550.03	337.78	240.95	578.73
S_{33}	248.95	193.44	442.39	253.00	200.27	453.27
S_{44}	871.08	657.94	1529.02	975.00	640.84	1615.84
S_{12}	1553.34	1371.56	2924.90	1698.15	1305.24	3003.39
S_{13}	754 40	994.72	1749.12	708.46	1229.39	1937.85
S_{14}	2427.76	2679.22	5106.98	2708.46	2653.09	5361.55
S_{23}	117.11	119.33	236.44	145.36	140.31	285.67
S_{24}	369.73	272.11	641.84	392.36	267.60	659.96
S_{34}	138.22	154.84	293.06	219.00	198.35	417.35

1 and 2, the following discriminant linear functions for the right and left femora are obtained:

$$X_R = 0.00019551\,x_1 + 0.00591114\,x_2 - 0.00069119\,x_3 + 0.00391106\,x_4$$

$$X_L = 0.00021523\,x_1 + 0.00661089\,x_2 - 0.00272120\,x_3 + 0.00378059\,x_4$$

in which x_1, x_2, x_3 and x_4 correspond to the four traits under consideration. For easier handling, the coefficient of x_1 may be regarded as equivalent to unity, with the following result:

$$X_R = x_1 + 30.2345\,x_2 - 3.5353\,x_3 + 20.0044\,x_4$$

$$X_L = x_1 + 30.7155\,x_2 - 12.6432\,x_3 + 17.5653\,x_4.$$

If the discriminant function is applied to the differences (d_1, d_2, d_3 and d_4) between averages of the traits under consideration, the difference D between averages of the discriminant functions in males ($\bar{X}$ male) and females ($\bar{X}$ female) is obtained. On both sides we have:

$$D_R = \bar{X}\ \text{male}_R - \bar{X}\ \text{female}_R = (0.00019551)(46.53) + (0.00591114)(6.17) - (0.00069119)(2.58) + (0.00391106)(10.57) = 0.0851254.$$

$$D_L = \bar{X}\ \text{male}_L - \bar{X}\ \text{female}_L = (0.00021523)(46.66) + (0.00661089)(6.19) - (0.00272120)(2.65) + (0.00378059)(10.49) = 0.0834112.$$

The analysis of variance may be effected with those values, arranged as follows:

	Sum of squares	Degrees of freedom	Mean Square	Ratio of variance	Probability
Right Femora					
Between groups	$nD^2/2 = 0.2246363$	4	0.0561590	78.511	Very small
Within groups	$D = 0.0851254$	119	0.0007153		
Totals	0.3097617	123			
Left Femora					
Between groups	$nD^2/2 = 0.2156803$	4	0.0539201	76.930	Very small
Within groups	$D = 0.0834112$	119	0.0007009		
Totals	0.2990915	123			

If we take as basis for the discrimination the midpoint between the two averages $\bar{X}$ male and $\bar{X}$ female, there will be error in the classification of individuals who vary more than $D/2$ from the average for their group. The ratio between $D/2$ and the standard deviation of X within the groups permits one to evaluate the proportion of the errors which will be made when applying the discriminant linear function. For the series examined in this paper we have:

$$t_R = \frac{0.0851254/2}{\sqrt{0.0007153}} = 1.5914 \qquad t_L = \frac{0.0834112/2}{\sqrt{0.0007009}} = 1.5753.$$

As we are working with 119 degrees of freedom and, like Mather ('43) we take into account that misclassification happens only in one direction, that is, that only the deviation corresponding to half of the area of the normal curve is of interest, the error becomes reduced to approximately 5% (5.6% and 5.7% of misclassifications for right and left femora respectively).

For appropriate checking we have applied the discriminant functions to each of the individuals included in the series of right and left femora respectively. The averages calculated with the individual discriminant values for the right femora (M male = 0.6369; M female = 0.5518) and for the left femora (M male = 0.6138; M female = 0.5301), agree with the theoretical ones previously obtained. Also in agreement are the t values now calculated starting with the differences between the averages (right: M male $-$ M female = 0.0851, and left: M male $-$ M female = 0.0837) and the sums of the squares (right: Male = 0.04792; Female = 0.03863, and left: Male = 0.05004; Female = 0.03315); the degrees of freedom being $n' + n'' - 2 = 122$:

$$t_R = \frac{0.0851/2}{\sqrt{0.08655/122}} = 1.598 \qquad t_L = \frac{0.0837/2}{\sqrt{0.08319/122}} = 1.603.$$

The t values for each trait separately also have been calculated following the same criterion as in the case of the discriminant function:

	1	2	3	4
Right	1.110	1.453	0.679	1.492
Left	1.100	1.417	0.684	1.440

These values are lower than those of the linear discriminant function. It is evident, therefore, that the overlapping variability presented by

males and females in each trait becomes smaller when the discriminant functions are used.

It is easy to prove that traits 2 and 4, that is, the diameter of the head and the width of the lower articulation, have t values not much lower than those for discrimination, while, on the other hand, the values of traits 1 and 3 are frankly lower. This calls for some explanation. In the first place we have our calculation for discriminant functions, for right and left femora, using only traits 2 and 4. Following Fisher's method, and without giving here the details of the calculations, the following discriminant functions are obtained:

$$X_R = 0.00617601\, x_2 + 0.00432041\, x_4 = x_2 + 0.699547\, x_4$$

$$X_L = 0.00616322\, x_2 + 0.00397473\, x_4 = x_2 + 0.644911\, x_4.$$

By applying these functions to each of the individuals in both series the following t values are obtained: 1.57 for right femora and 1.55 for left femora. This shows that traits 1 and 3 do not appreciably increase the discrimination. In any case, whenever possible when considering a specific case, it is advisable to use the function of 4 traits as the result will in general be less influenced by chance than if two traits are used, and still much less than if only one trait is used.

DISCRIMINATION IN THE STERNUM

The material studied is part of the excellent collection of "identified skeletons" of the Anthropological Museum and Laboratory of Coimbra University. It consists of 272 sterna of adult Portuguese people metrically and morphologically studied by Serra ('41).

As is the case with most of the bones of the skeleton, the sternum is larger in males than in females. The following traits have been chosen because they afford greater discriminant values: 1) total curvilinear length; 2) total rectilinear length; 3) rectilinear length of the corpus; 4) maximum sub-costal width of the manubrium; and 5) minimum width of the corpus. They are absolute measurements; the indices present small sexual differences in the sternum.

For the calculation of the discriminant function we use now the "size-shape" method of Penrose ('47) because, with 5 traits examined, Fisher's method would be more laborious to employ since for the m traits it requires the calculation of $\frac{1}{2}m(m-1)$ sums of products, m

sums of squares, and the solution of a system of m equations with m unknown quantities.

In table 3 are shown the averages of each trait, expressed in terms of common standard deviation and reduced to a common zero mean.

The "size" value of Penrose, represented by Q, is the result of the sum of the values of the 5 traits in each individual; and the difference Q between males and females is:

$$D_Q = Q \text{ average in males} - Q \text{ average in females} = 9.2220.$$

The "shape" value, repersented by P, is obtained by adding the

TABLE 3

Mean Measurements Expressed in Terms of Common Standard Deviation and Reduced to Common Zero Mean

Traits	Males	Females	Difference Male-Female
1. Total curvilinear length	+ 1.1563	— 1.1563	+ 2.3126
2. Total rectilinear length	+ 1.2621	— 1.2621	+ 2.5242
3. Length of the corpus	+ 1.0258	— 1.0258	+ 2.0516
4. Maximum width of the manubrium	+ 0.6248	— 0.6248	+ 1.2496
5. Minimum width of the corpus	+ 0.5420	— 0.5420	+ 1.0840
	+ 4.6110	— 4.6110	+ 9.2220

product of each of the 5 traits by the coefficients k (table 4). The value of the shape difference is:

$$D_P = P \text{ average in males} - P \text{ average in females} = 0.8984.$$

Q and P values, as well as their respective variances and covariances Q/P, were calculated for each individual in both series. By taking for each of these values the average between males and females, and bearing in mind those for D_Q and D_P, the following α is obtained according to the Penrose method:

$$\alpha = \frac{D_Q \text{ Var. } P - D_P \text{ Cov. } QP}{D_P \text{ Var. } Q - D_Q \text{ Cov. } QP} = \frac{(9.2220)(0.6334) - (0.8984)(0.8776)}{(0.8984)(14.5613) - (9.222)(0.8776)}$$

$$= 1.0130$$

and as the best combination of "size" and "shape" is $L = \alpha Q + P$ we have:

$$L = 1.0130Q + P.$$

That function was applied to each of the individuals in both series. Two series were prepared with the individual discriminant values, and the value t was calculated with the difference between the averages (M male $- M$ female $= 10.0605$) and the sums of squares (males

TABLE 4

	$\bar{\delta} - \bar{\varphi}$	$k = \frac{5(\bar{\delta} - \bar{\varphi}) - 1}{9.2220}$	$\bar{\delta} \cdot k$	$\bar{\varphi} \cdot k$	$\bar{\delta} \cdot k - \bar{\varphi} \cdot k$
1. Total curvilinear length	+2.3126	+0.2538	+0.2935	—0.2935	+0.5870
2. Total rectilinear length	+2.5242	+0.3686	+0.4652	—0.4652	+0.9304
3. Length of the corpus	+2.0516	+0.1123	+0.1155	—0.1155	+0.2310
4. Maximum width of the manubrium	+1.2496	—0.3225	—0.2015	+0.2015	—0.4030
5. Minimum width of the corpus	+1.0840	—0.4123	—0.2235	+0.2235	—0.4470
	+9.2220	—0.0001	+0.4492	—0.4492	+0.8984

$= 2301.06$ and females $= 2400.73$), in accordance with the criterion set down above:

$$t = \frac{10.0605/2}{\sqrt{4701.7952/270}} = 1.21 \text{ (11.3\% of erroneous classifications).}$$

That is to say, the probabilities of correctness in distinguishing the sex of sterna are 89%.

SUMMARY

1. The use of discriminant functions, calculated on the basis of quantitative traits, to ascertain the sex of human remains and for the purpose of eliminating the personal judgment in diagnosing, is discussed.

2. For that purpose, data are made available on femora and sterna

of individuals whose sex is positively known, instead of diagnosed, a necessary condition when testing the method of calculation.

3. With Fisher's method, discriminant functions are obtained which permit the sexual distinction of right and left femora with probabilities of accuracy approaching 95%. Likewise, in a series for sterna an accuracy of discrimination of 89% may be obtained with the Penrose method.

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BODY COMPOSITION AND BASAL METABOLISM IN MAN: CORRELATION ANALYSIS VERSUS PHYSIOLOGICAL APPROACH [1]

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WHILE the relation between basal metabolic rate (BMR) and body size has been examined in numerous studies (cf. Kleiber, '47), there is much less information on BMR and body composition, in the chemical and anatomical sense. Basal metabolic rate represents the sum of energy metabolism of all the cells of the body under standard conditions. Since there are in the body various kinds of cells, differing in the rate of oxygen consumption, it is clear that BMR must be related to the proportion of the different cells or tissues constituting the particular body.

Several attempts have been made to "partition" the total basal oxygen consumption of the animal body among its different organs or tissues but progress in the solution of the problem, clearly stated by Barcroft as far back as 1908, has been slow. In the last few years, however, the development of methods for determining the composition of the human body *in vivo* has given a new impetus to this type of studies. The correlations between different components or compartments of the body and BMR were investigated by several authors. Such studies are important both from a theoretical and a practical point of view. A better knowledge of these relationships is essential for the understanding of the physiological factors which govern the magnitude of the BMR. Also, it will provide a more adequate basis for establishing BMR norms, used for the comparison of the different individuals

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and the evaluating of the deviations from "normality," than can be obtained from the height and gross body weight alone.

Two main approaches have been followed in the studies of the relationship between body composition and BMR. On the one hand, it has been possible to measure directly, by physiological techniques, the oxygen uptake of various organs of the human body, *in vivo*, and to evaluate their share in the basal oxygen consumption of the intact body. We will refer to this method as "physiological approach." On the other hand, the study has been pursued by applying the methods of statistical analysis and calculating the coefficients of correlation between the magnitude of some compartments of the body and the BMR. We shall speak in this case of "statistical approach." Unfortunately, the evaluation of the latter data has not always been carried out with the necessary care and caution, and in some cases the interpretation of the correlational analysis conflicts with the results obtained by the direct methods (the "physiological approach").

Modern statistical methods provide useful tools for the design of biological and medical investigations and for the scientific analysis of the data. At the same time, the increasing complexity of statistical operations magnifies the danger of an incorrect biological interpretation of the correctly computed statistics. This danger is present even when elementary statistical concepts and procedures, such as correlational analysis, are used.

In correlational analysis, as applied to the study of basal metabolism and body composition, the *association* between specific criteria of body composition and basal metabolism has been interpreted by some authors incorrectly in terms of *causation*. While valid information obtained by statistical analysis of data on total oxygen intake and a body compartment is limited to individual *differences* (interindividual variation) and the *covariation* of basal metabolism with morphological characteristics, erroneous inferences have been made on the *partitioning* of basal oxygen consumption among different body compartments. Such incorrect conclusions, based on careful measurements and correctly ascertained statistical relationships, have crept into a recent paper by Garn, Clark and Portray ('53).

The authors stated clearly (p. 166): "Muscle and fat together account for the major proportion of the child's oxygen needs under basal conditions." In summarizing their findings they wrote (*loc. cit.*): "Together fat and muscle accounted for over 70% of the basal oxygen

consumption." This conclusion was based on the fact that the coefficients of correlation between BMR and the calf muscle measurements (maximum antero-posterior diameter) were 0.82 for boys and 0.73 for girls; for "fat" (difference between total diameter and the muscle diameter), the values were 0.30 and 0.35, respectively; no coefficients of multiple correlation were reported in which "fat" and "muscle" were combined.

With the variance of the basal consumption values taken as unity, one must beware of simply adding the proportions accounted for by each of the several criteria of body structure (such as skinfolds, limb circumferences, or bony dimensions). By such a procedure one could readily exceed unity. It is the coefficient of multiple correlation, squared, which must be used in determining the amount of variation in one measurement, such as basal metabolism, accounted for on the basis of several other measurements considered simultaneously. Even this procedure remains limited to "external," *statistical associations* which say or imply nothing about "internal," *physiological dependence.*

In view of the current interest in the analysis of the relationships between body composition and BMR, it seems desirable to attempt to clarify the essential differences between the correlational analysis and the direct estimations of oxygen consumption. It is hoped that a critical examination of these two approaches to the problem will be helpful in correctly interpreting available data and will encourage the integration of fundamental information obtained by different methods.

CORRELATIONAL ANALYSIS

Because of the difficulty of a direct, "intuitive" interpretation of a coefficient of correlation, the r is perhaps the least useful way of expressing the association between two variables. For purposes of prediction, the relationship is expressed in the form of a regression equation of the type $Y = a + bX$, togethed with the standard error of estimate ($SEE_Y = SD_Y\sqrt{1 - r^2_{XY}}$) which serves as an absolute criterion of how "good" is the correlation between Y (basal metabolism) and X (a measure of body composition).

When one wishes to indicate how much of the total variation in basal metabolism is accounted for by the regression, it is necessary to use the coefficient of determination, r^2. This can be written simply as $r^2 = (SD_{\hat{Y}})^2/(SD_Y)^2$. The ratio, then, indicates the fraction of the

variance of the Y values which is statistically accounted for on the basis of the association of Y with X. It is in this sense that Garn and his co-workers wrote "Together these two tissues, muscle and fat, appear to account for at least 70% of the total interpersonal variance in the basal metabolic rate in the age group considered."

However, the argumentation was switched from a *statistical* into *physiological* accounting, from the analysis of covariation between body structure and basal metabolism to the partitioning of basal oxygen consumption. The fraction of interindividual variance in oxygen intake, accounted for statistically on the basis of correlations with the linear calf dimensions and indicated by r^2, can not be identified with the fraction of the total basal oxygen consumption represented by the energy metabolism of skeletal muscles and the adipose tissue.

Researches on tissue and organ respiration indicate that the partition of the basal oxygen consumption is strikingly different from that inferred from the correlational analysis. On the basis of our present knowledge, muscle and adipose tissue will in no case account for 70% of the total energy metabolism of the human body under standard resting condition.

PHYSIOLOGICAL PARTITIONING OF BASAL OXYGEN CONSUMPTION

Information is available on the oxygen consumption of many of the organs of the human body under resting conditions. This makes possible approximate partitioning of the total oxygen consumption of the resting man. A calculation of the relative participation of the different organs in the total oxygen consumption was made some time ago by one of us (Grande, '50) and by Drabkin ('50). Since additional data have been published in the last few years, it may be appropriate to reevaluate the share of the different tissues and organs in man's basal oxygen consumption. In order to make such estimations we have to know the rates of oxygen consumption in different tissues and the mass of these tissues.

To begin with the single largest anatomical component, the amount of muscle tissue in the normal adult man is generally estimated to be about 40% of the total body weight. In table 1 two values are cited from the classical German literature, together with recent measurements made by American authors. The average amount of muscle in the "normal" adult man is not over 40% of the total body weight and is probably less than that.

As to the amount of oxygen consumed by resting human muscle, the figure of 0.17 cc O_2 per 100 gm per minute was obtained by Asmussen, Christensen, and Nielsen ('39). The recent direct determinations made by Mottram ('54) yield an average value of 0.245 cc per 100 cc muscle per minute, with a standard deviation of 0.07 cc. This value, corrected for the density of muscle, gives a value of 0.23 cc O_2 per 100 gm of muscle per minute. By applying these figures to the values of muscle mass it is possible to estimate the oxygen consumption of the total musculature of a "normal" man. A minimal value of some 37.4 cc per minute and a maximal value of 69.2 cc is obtained. Taking 250 cc O_2 per minute as the value of the basal metabolic rate of a normal adult man, the above figures would correspond to 15% and

TABLE 1

Measured amounts of skeletal muscle tissues in the human body

Author	% of Total Body Weight	Kg in a 70 Kg Man
Theile (Suárez, '52)	35.9	25.1
Vierordt ('06)	43.0	30.1
Mitchell, *et al.* ('45)	31.5	22.0
Forbes, *et al.* ('53)	39.7	27.8

28%, respectively, of the total oxygen used. It is clear, therefore, that even using the highest value the musculature could not contribute more than some 30% of the total basal oxygen consumption.

A comparison of the O_2 consumption of the musculature with that of some important organs may be instructive. In table 2 the values were calculated for the liver, brain, heart and kidneys as well as for the musculature, using for total muscle the value of 39.7% of the total body weight found by Forbes *et al.* ('53), and the values for oxygen consumption of the different organs given in the literature.

From the foregoing calculations it can be concluded that the internal organs account for over 60% of the total basal oxygen consumption. The remaining organs and tissue other than muscles (skin, bones and bone marrow, lungs, adipose tissue, etc.) undoubtedly have a certain, though small, consumption of oxygen. In view of the existing experimental evidence it is impossible to accept an oxygen consumption for the human resting musculature much higher than some 25% of the basal oxygen consumption of the total body.

As to the oxygen consumption of the adipose tissue, there is general agreement that it has a very low energy metabolism and the calculations of table 2 indicate that this cannot be greater than a fairly small fraction of the 13% to 14% of the basal oxygen consumption not accounted for by the metabolism of liver, brain, heart, kidney and skeletal muscle.

TABLE 2

Physiological partitioning of basal oxygen consumption in the normal adult man (body weight, 70 kg; body surface, 1.73 m²; resting oxygen consumption, 250 cc O_2 per minute).

Organ	Weight, gm	Weight, % total body	Oxygen consumption, cc/100 gm/minute	Total O_2 consumption	% of BMR
1. Liver (a)	1,500	2.1	4.4	66	26.4
2. Brain (b)	1,400	2.0	3.3	46	18.3
3. Heart (c)	300	0.43	9.4	23	9.2
4. Kidneys (d)	300	0.43	6.1	18	7.2
			Subtotal (1-4)	153	61.1
5. Skeletal muscles (e)	27,800	39.7	0.23	64	25.6
			Total (1-5)	217	86.7

(a) Includes total oxygen consumption of "splanchnic area." *Cf.* Bradley *et al.* '45; Myers, '47; Myers and Holland, '49; Dobson *et al.*, '53.

(b) Kety and Schmidt, '48; Scheinberg and Stead, '49; Heyman *et al.*, '50; Stead, '50; Bentinck *et al.*, '51; Schieve *et al.*, '51; Novak *et al.*, '53.

(c) Calculated assuming left ventricle = ⅔ of total heart weight. The oxygen consumption rate of the right ventricle is assumed to be ½ of the left ventricle. *Cf.* Bing *et al.*, '49, '50.

(d) Cf. Bradley and Halperin, '47; Clark and Barker, '49; Smith, '51.

(e) Calculated with Mottram's ('54) figure corrected for muscle density.

COMMENT

In recent years a good deal of progress has been made in the partitioning of the body, *in vivo*, using external body measurements, including skinfolds, X-rays, body density, and body water and its fractions (for a summary cf. Brožek, '53; Keys and Brožek, '53). This provides new tools and a new frame of reference for the analysis of biochemical processes and physiological functions which are related to the composition of the body.

It has been noted that the basal oxygen consumption of different tissues and organs varies markedly. Consequently, the separation of gross body weight into components which have no or low energy metabolism (extracellular water, bone mineral, fat) and those which are characterized by substantially higher oxygen requirements appears useful. Theoretically, at least, a better reference point for the evaluation of normality of the basal oxygen consumption is provided by such separation than by using gross body weight or other derived values, such as the surface area calculated from weight and height. The significance of changes in basal metabolism observed in prolonged caloric deprivation (Keys *et al.*, '50) or in the course of aging (Brožek, '52) may be interpreted physiologically more correctly when these changes are referred to the "fat-free body mass" or "active tissues" (the latter being defined as body weight minus the weight of fat, bone mineral, and extracellular fluid) than to gross body weight.

"Active tissue mass" represents the sum of bodily tissues which participate more actively in the resting energy metabolism of the body. The concept is useful and progress in the estimation of different body compartments has made possible a more objective characterization of its boundaries.

However, the physiological partition of the basal oxygen consumption of the human body points out some important limitations which should be borne in mind when speaking of "active tissue" mass. It is not an homogeneous mass of tissues all having an identical metabolic rate. The figures given in table 2 clearly indicate that the "active mass" of the body is in fact made up of a relatively small mass of visceral organs (liver, brain, kidneys, heart, etc.) with a relatively high metabolism under resting condition of the body, and a much greater mass with a relatively low resting metabolic rate, constituted by the skeletal musculature. Obviously, the "active tissue mass" can not be identified with the skeletal musculature.

The erroneous idea that the skeletal muscles have a large share in the total oxygen consumption of the body at rest has a long tradition in physiological thinking. In his classical review of 1908 Barcroft criticized the idea put forward by the French physiologist Richet, according to which the musculature makes up over 90% of the total oxygen consumption of the resting body. This idea seems to persist in the minds of present-day physiologists, who, in speaking of active tissue mass or "metabolically active mass," tend to identify it with the skeletal musculature.

The resting metabolic rate of the human body is no doubt a measure of the "active mass," but, as this mass is made up of different components with different metabolic rates, it is impossible to translate the BMR figures directly into actual weight of the "active tissue mass." Obviously, a change in the proportions of the components of the "active mass" will produce changes in the basal metabolic rate, without a change in the total mass.

It has been stressed earlier that a statistically significant correlation between two variables does not prove any direct causal relationship in a physiological sense. The association may be indirect and result from the correlation of both variables with other variables. The interpretation of a coefficient of determination in terms of the share of a body component in the basal metabolism can be reduced *ad absurdum* by considering the high correlation between the fluid compartments of the body and the basal oxygen consumption. Thus Wedgwood *et al.*, ('53) reported an r of 0.80 between interstitial fluid and basal metabolic rate. While this fluid compartment "accounts" statistically for 64% of the variation in the BMR, its actual participation in the body's oxygen consumption must be practically zero. No direct causal relationship is present at all, in spite of the fairly close parallelism between the two variables.

SUMMARY AND CONCLUSIONS

Statistical "accounting" for a quantitative phenomenon, such as basal metabolism, consists in comparing the variance of the values ($\hat{Y}$), predicted on the basis of the criterion (X), with the variance of the dependent variable (Y).

With X representing a muscle diameter (or a more direct measure of muscle mass) and Y representing the basal metabolism, the coefficient of determination (r^2) cannot be interpreted as the relative share of the muscle mass in basal oxygen consumption.

Direct determinations of the oxygen consumption of human muscles, based on the rate of blood flow and the arterio-venous oxygen difference, suggest that in the resting state the skeletal musculature is responsible for only about 25% of the amount of O_2 consumed by the body.

The separation of the body into components which have a low or no energy metabolism (fat, extracellular fluid, bone mineral) and those which are characterized by a substantially higher oxygen intake is useful. However, it should be kept in mind that the "active tissue mass,"

obtained as the difference between body weight and the sum of the weights of the "inactive" compartments, is heterogeneous in composition and in the rate of oxygen uptake of its components.

The "active tissue mass," under resting conditions, can not be identified with the muscle mass.

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VENEREAL DISEASE CONTACTS OF A SPECIFIC GROUP OF MEN IN A 5-DAY PERIOD

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VENEREAL disease continues to be one of the major problems for all medical officers in the Armed Forces, especially in overseas areas. The incidence of such disease is directly related to three factors, namely, incidence of exposure, effectiveness of available prophylaxis, and how such prophylaxis is used. The purpose of this paper is to report the incidence of exposure of a given group of enlisted men during a 5-day period.

Prior to the work of Kinsey and associates ('48), little statistical information was available as to prevailing sexual activities of men. Most of the information was based on individual case histories primarily from the psychiatric literature, "clinical impression," and personal experience. Owing to different educational, social and economic backgrounds and the fading of youth, many line officers and medical officers are unaware of the extent of sexual activities of young enlisted men. It is hoped the present report will supply additional information on the incidence of exposure for those concerned with the control of venereal disease.

In 1949, the author was attached to a group serving in the Far East. For two months the enlisted men concerned had been in a cold climate with little in the way of liberty or recreation. Opportunities had been available and a few of the less esthetically inclined had contracted various venereal diseases, but the over-all incidence was about the same as for all military units in the area. Then, after the group spent 5 days in one of the more modern cities of Asia in a warm climate, with liberty being granted to two thirds of the crew from 1 p. m. to midnight each day, more venereal infection developed in a few days than had been encountered in the preceding few months. Prior to this liberty extensive

lectures on venereal disease and prophylaxis had been given, educational movies had been shown, and all available types of prophylactics had been provided.

A questionnaire was prepared for the purpose of finding out which one of the three variables mentioned in the first paragraph was responsible for this great increase in venereal disease. The questionnaire was passed out 4 days after the liberty period had ended and while the men were at sea returning to their usual duty bases. With the men at quarters, it was announced over the public address system that the medical department was greatly concerned over the sudden increase in venereal disease, that the co-operation of the men was needed to plan more effective treatment for the future, that the information was to be used only by the medical department and that the questionnaires would remain anonymous. The questionnaires and pencils were distributed and rapidly collected, the entire time, including that used for the announcement, not exceeding 10 or 15 minutes. The questionnaire included the following items:

1. Age.
2. Married or single.
3. Is this your first or second trip to the Far East (or more)?
4. How many times did you go on liberty in [the designated city]?
5. Do you drink alcoholic beverages?
6. How many sexual contacts did you have in [the designated city]?
7. How many sexual contacts were made after drinking?
8. Would you have made these sexual contacts if you had not been drinking?
9. How many times did you use only a rubber condom?
10. How many times did you use only a Navy sanitube?
11. How many times did you use both a condom and a sanitube?

Approximately 200 of the questionnaires were distributed and 188 were returned. Of these, 5 represented men who had not been on liberty, and 11 were improperly filled out (interestingly enough, only one of these facetiously); hence, there remained 172 questionnaires which form the basis of this report. Of the 172 men, 126 were single, 45 were married and one was divorced.

In regard to the number of trips to the Far East, 83 single men were on their first, 36 were on their second and 7 were on at least their third trip. The corresponding figures for the married men were 26 on

the first trip, 14 on the second and 5 on at least the third trip. Combining the figures, one finds that 64% of all the men were on their first trip, 29% were on their second trip, and 7% were on at least their third trip. The single men had a total of 366 liberties, the married men had 131 liberties and the one divorced man had 4 liberties. This makes a total of 501 liberties by the entire group during the 5 days for an average of 2.9 liberties per man. There was no significant difference in the number of liberties the single men had as compared to the married men—they all went on liberty as often as they could.

TABLE 1

Contacts Made in the 5-day Period by the Given Number of Men, Tabulated According to Age and Marital Status

Age	Marital status	Contacts 0	1	2	3	4	5	6	7	8	9	10	11	12	16	Total
17	Single	2	4													6
	Married															
18	Single	6	10	6	1	2	1		1		1					28
	Married			1												1
19	Single	6	9	2			1							1		19
	Married		1													1
20	Single	5	5	4	4	3	1			2	2			1		27
	Divorced											1				1
	Married			1	1											2
21	Single	4	3	2	3	1	4							1		18
	Married	2			1											3
22	Single	5	1				1	1								8
	Married			3	1											4
23	Single	2	1	3				1								7
	Married	3		1												4
24	Single		2	1			1	1								5
	Married	1	1	1	1	1										5
25	Single			1												1
	Married	1		1	1											3
26	Single	1														1
	Married				1	1							1			3
27	Single				1										1	2
	Married	3		2												5
28+	Single	2		1		1										4
	Married	9	2	1	2											14
Total		52	39	31	17	9	9	3	1	2	3	1	1	3	1	172

Table 1 shows the number of contacts made by the men during the 5-day period. (For the purposes of this study, a contact is defined as an act of intercourse.) For example, of the 17-year-old single men, two had no contacts and 4 had one contact each. One may summarize this information by saying that the entire group had a total of 374 contacts. These were made by 120 men for an average of 3.1 contacts per man. On a percentage basis, 70% had contacts. The 93 single men had a

TABLE 2

Relation of Use of Alcohol to Number of Contacts

Age	Do you drink alcohol? Yes	No	Would you have had contacts if not drinking? Yes	No	Contacts made after drinking 1	2	3	4	5	6	7	8	11	12
17	6		3	1										
18	24	4	20	3	10	2		2			1	1		
19	19	2	14		6	1								
20	27	2	20	4	5	6	3	3		1		1		
21	17	4	14	1	2	3	3	1	2					
22	11	2	4	3	3	1		1						
23	10	1	5	1	1	3				1				
24	10		9		4	2	1			1				
25	4		3			2	1							
26	4		2				1	1					1	1
27	5	2	4				1							
28+	15	3	5	3	2	3								
Total	152	20	103	16	33	23	10	8	2	3	1	2	1	1

total of 295 contacts, which means that 74% of the single men had contacts and averaged 3.2 contacts per man. The 26 married men had a total of 69 contacts, which means that 58% of the married men had contacts and averaged 2.7 contacts per man.

Alcohol is undoubtedly a factor in the transmission of venereal disease. Shakespeare noted that alcohol "Provoketh the desire. . . ." In the present study the author tended to blame the cheap and abundant alcohol for the great amount of sexual activity during the 5 days of liberty. Most of the information obtained from the questionnaire in regard to the use of alcohol is shown in table 2.

The information about alcohol can be summarized as follows: one hundred and fifty-two men or 88% stated that they used alcohol, there

being little difference here between the married and single men. Of the 374 sexual contacts, 215 or 57% were made after drinking. There was found to be some difference here between the married and the single groups, as 81% of the contacts by married men were made after drinking while only 53% of the contacts made by the single men were after drinking.

The question "Would you have had these contacts if you had not been drinking?" was used as a check on the reliability of the answers. It was felt that if a man answered "yes" to this question, then most of his other answers probably would be reliable. On the other hand, if he were seeking an "out" or justification for his actions and did drink, he would have been inclined to blame the alcohol and answer this question "no." Of those answering the question, 103 out of 119 did so in the affirmative. On a marital basis, 8 of 93 single men and 8 of 26 married men blamed the alcohol.

Because the types and methods of prophylaxis used by the Armed Forces have changed considerably since this study was made in 1949, no detailed analysis of this information will be given here. It suffices to say that of the 120 persons having contacts, only 26 failed to use any protection at all. They had 91 unprotected contacts or 24% of the total made by the group.

The next step in this study was to see if there was any significant difference between the behavior of this group of 172 men who, for the most part, did not contract a venereal infection and another group of men who did. The latter group consisted of 49 patients. These were obtained from 4 similar groups of men who had spent 5 days in the city and to whose records the author had access, 10 of these patients being from the original group of some 200 men on which the major part of this paper is based. Of these 49 patients, the author was able to interview 39 and gather data on behavior. Hence, these 39 men make up the venereal disease group on which the following comments are based.

Eight of the 39 venereal disease patients were married. The average number of contacts, 2.3 per man, was the same for married and single men. This rate is actually somewhat less than those for the control group of 172 men (2.7 for the married and 3.2 for the single men), although it is doubtful that the difference is significant. The group of men contracting an infection was essentially similar to the control group in age, number of liberties, trips to the Far East, and so forth. The only striking difference was that 96% of the contacts by the group who contracted an infection were made after drinking as compared to

57% for the control group. Moreover, the group who contracted an infection used some form of prophylaxis for only 45% of their contacts as compared with 76% for the control group. Thus alcohol does not seem to play much of a role in determining whether or not the men will have sexual contacts, but those who do drink use less precaution and are more likely to contract an infection than are those who do not drink.

During the time the author was interviewing the men who had contracted an infection the study was reviewed by the area consultant in psychiatry. At his suggestion and in the hope of finding further information as to why these men happened to contract an infection, histories of sexual development were taken where possible. The results are given in table 3. It is of interest to note that 12 of 15 men had experienced intercourse before they reached the minimal military age of 17 years. This suggests that their behavior patterns were well established before they entered military service, and hence it seems to contradict the charges sometimes made that the Armed Forces corrupt the morals of men.

These 39 cases are too few to permit the drawing of any conclusions as to the type of person who contracts a venereal infection. The frankness of some of the answers, however, would tend to indicate that the data are probably reliable.

SUMMARY AND CONCLUSIONS

This is a report primarily on the sexual contacts of a group of 172 enlisted men. While some of the figures may seem unlikely, all are within the ranges for sexual activity as listed by Kinsey and co-workers. During 5 days of liberty, 70% of the men had contacts. While 88% of the men stated that they used alcohol, only 57% of the contacts were made after drinking. Of those who answered the specific question, more than 80% said they would have had the contacts whether they had been drinking or not. The behavior of this group has been compared with that of a smaller group of men who did contract venereal infections. The main difference seems to be that the group contracting infections more often used alcohol before and less often used protection during contacts than did those who escaped infection.

The author wishes to emphasize that these data represent the action of a given group of men under a given set of circumstances. No conclusions are drawn as to whether this reported behavior is normal or

abnormal, as to whether it is representative of young men in the Armed Forces, or as to whether it is even representative of the usual behavior of this group of men.

TABLE 3

Data on Sexual Development

Case	Age	Contacts in city	Education (years)	Age first mastur-bated	Age first inter-course	Age or time last masturbated	Approx. range of contact per week in States (before Far East)	Married or single
A–W–1	17	1 for 1	11	11	15	15	4–12	S
B–H–10	19	3 for 12	12	11	17	18	3–4	S
B–H–11	21	6 for 10	12	12	15	16	2–3	S
B–H–12	17	2 for 4	9	11	17	2 wk. ago	1–2	S
B–H–13	20	2 for 20	9	12	15	15	9–12	M
B–H–14	27	2 for 7	12	11	14	15	1–2	M
B–H–15	22	2 for 3	7				2–3	S
B–H–16	20	3 for 10	10	12	16	2 wk. ago	1–2	S
C–B–1	22	1 for 1	11	11	15	7 mo. ago	1–2	S
C–B–2	18	3 for 3	12	12	17	1 mo. ago	1–2	S
C–B–3	21	2 for 2		12	16	17	1–2	S
D–T–4	18	3 for 13	10	11	13	15	< 1/wk.	S
D–T–5	19	1 for 10	12	11	14	3 mo. ago	< 1/wk.	S
D–T–6	18	3 for 10	8	14	14	1 mo. ago	3–4	S
D–T–8	18	1 for 2	11	12	16	10 mo. ago	3–4	S
D–T–9	21	1 for 7	11	12	14	3 mo. ago	4–6	S

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FAT ACCUMULATION AND WEIGHT GAIN IN THE ADULT MALE

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INTRODUCTION

BY THE third decade of life the male has reached maturity, a life-phase marked by a cessation of vertical growth. The termination of skeletal increases, however, and an abrupt end to increments in "operational" tissue often herald a gain in fat-containing tissue, and progressive alterations in the surface contours.

These changes in the deposition and accumulation of fat, though unaesthetic and possibly linked to later degenerative disorders, are of particular interest to the student of growth and form. For the thickness of the subcutaneous fat layer is accessible to measurement, and the analysis of simultaneous changes at different parts of the body provides insight into one aspect of changing body form.

At the same time studies dealing with the deposition of fat are valuable in comprehending the meaning of "normal" weight, and the significance of weight changes. It is not how heavy a man is or how heavy he becomes that has maximum prognostic significance, but rather how much fat he carries and how much fat he adds. It is not unlikely that the location of the fat, as well as the gross amount, may elucidate the differential mortality rates of the different weight groups.

Without reviewing the growing bibliography on body composition (see Brožek, '53; Reynolds, '51) it is sufficient to say that only limited information is available on the thickness of uncompressed subcutaneous fat-containing tissue in adult males (Garn, '54) and that fewer data have been published on the differential increase in subcutaneous fat with advancing age and weight. Moreover the possibility of using such data

in the analysis of form has not been a stated aim of most published research in this field.

It is the purpose of this communication, then, to report on age-associated changes in 9 measured thicknesses of the subcutaneous fat in adult males, and to express these changes in relation to measured weight and the estimated weight of fat. It is a further purpose to express these fat-thickness and fat-weight relationships in a manner that may be helpful in comprehending how the superficial fat-containing layer alters its configurations as the totality of fat becomes greater or less.

METHODS AND MATERIALS

Roentgenographic and other studies were made on a total of 85 white males from 20 to 69 years of age. All were active and reasonably healthy and were for the most part parents of participants in the Fels longitudinal growth investigations. Occupationally the group included farmers, professional and semi-professional workers. In terms of national origins, all except two were of Northwest European ancestry. One extremely obese male weighing 140 kg and one male with multiple congenital defects were not included in the tabulations.

Besides routine measurements of height (standing) and weight (nude), a total of 9 fat-shadow measurements were made on standardized soft-tissue teleoroentgenograms, using a micrometer caliper with ground tips (Garn and Saalberg, '53). The fat shadow measurements included deltoid-insertion fat, lateral arm fat, medial arm fat, iliac fat, trochanteric fat, posterior leg fat, anterior leg fat, medial leg fat and lateral leg fat. The location of the sections X-rayed and measured as well as the poses adopted are shown in Garn ('54).

The creatinine values used in this study are based on full 24-hour urine collections, acidified and refrigerated until analysed. Determinations were made as described by Clark and Thompson ('49) using the Beckman spectrophotometer and a creatinine standard. All values were expressed as creatinine (in milligrams) per 24 hours.

The estimated weight of fat, as reported here, was based on the trochanteric fat thickness, since it has been shown that trochanteric fat is the best single indicator of subcutaneous fat thickness in general and, of the 9 thicknesses measured, it is best correlated with weight (Garn '54). The weight of fat, corresponding to a given trochanteric fat thickness, was computed from the correlation coefficient between trochanteric fat and weight, and the standard deviations of weight and

trochanteric fat respectively. It may be thought of as the weight that would have to be deducted from the subject's observed weight, if he were reduced to a trochanteric fat thickness of 0.[1]

FINDINGS

As shown in table 1, 8 of the 9 fat-containing layers measured exhibited an age-associated increase, with the maximum gain both absolute (7.8 mm) and relative (58%) attained by the iliac fat. The three thickest layers, iliac, trochanteric and deltoid-insertion fat all increased 3 mm or more. The 6 distal fat layers, thinner to begin with showed smaller absolute gains, and smaller percentage increases. Notably, the rate of increase of iliac fat out-paced that of the other fat layers, so that by the fifth decade iliac fat was the thickest, reversing its earlier ranking. The data do show that there is a tendency to deposit fat differentially over the pelvic region. However it is evident that the rate of increase differs even on different quadrants of the lower leg, and that the deltoid-insertion fat falls between the "central" and the "distal" fat both anatomically and in its pattern of gain.

Over the 4 decades considered here, weight also rose, paralleling the increase in fat. In weight, as in fat thickness, the change was more rapid between the third and fourth decades. The curvilinear nature of these changes made η rather than r the appropriate measure of relationship with age. As shown in table 1, the etas approach or exceed significance at the 5% level, though it is acknowledged that the meaning of a given value of η is open to question (Fisher, '48, p. 256).

Since the estimated weight of fat is derived from the trochanteric fat thicknesses, this later value parallels the increase in trochanteric fat, rising from 11.5 kg in the third decade, to 17.3 kg in the sixth. If computed as a percentage of gross body weight, the change is from 15.6% to 22%, a not unreasonable value when compared to other studies. The same data computed upon an individual basis suggest a lean body weight (gross weight minus estimated fat weight) of 61.5 kg in the third decade, 60.4 kg in the fourth decade, 61.4 kg in the fifth, and 58.9 kg in the sixth. The creatinine values, obtained on 30 of the

[1] In computing the estimated weight of fat, from the regression of weight on trochanteric fat, and in computing the estimated fat-free weight (observed weight minus estimated weight of fat) no corrections for stature were made since the mean stature was substantially the same for all 4 age-groups.

subjects over 30 years of age show a negative relationship with age, with the regression equation being Creatinine = —7.56 Age + 2112. It should be noted, however, that the stature of the oldest age group (175.3 cm) is also the lowest by nearly 2 cm so that a possible decrease in muscle mass, as suggested by the creatinine trend, may be attributed to smaller size, rather than to an actual loss of muscle.

TABLE 1

Age changes in fat thicknesses, weight and estimated fat weight

Measurement		Age group 20–29	30–39	40–49	50–	Relationship with age (r)
No. of men		15	18	32	20	
Age	(yrs)	24	34	44	55	
1. Deltoid insertion fat	(mm)	14.8 ± 1.3 [1]	18.6 ± 1.1	18.7 ± 0.6	18.3 ± 0.8	0.31
2. Lateral arm fat	(mm)	4.2 ± 0.5	4.7 ± 0.4	4.3 ± 0.3	5.1 ± 0.4	0.21
3. Medial arm fat	(mm)	3.2 ± 0.3	3.3 ± 0.3	3.4 ± 0.2	4.1 ± 0.3	0.25
4. Iliac fat	(mm)	13.5 ± 1.9	17.9 ± 2.0	20.8 ± 1.3	21.3 ± 2.2	0.34
5. Trochanteric fat	(mm)	12.3 ± 1.9	16.6 ± 1.4	17.5 ± 1.2	18.4 ± 1.5	0.30
6. Posterior leg fat	(mm)	6.5 ± 0.7	7.3 ± 0.6	6.9 ± 0.4	8.2 ± 0.4	0.23
7. Anterior leg fat	(mm)	2.8 ± 0.2	2.8 ± 0.1	2.6 ± 0.1	2.8 ± 0.2	0.04 [2]
8. Medial leg fat	(mm)	5.0 ± 0.5	6.3 ± 0.6	6.2 ± 0.4	7.3 ± 0.7	0.30
9. Lateral leg fat	(mm)	4.1 ± 0.4	5.3 ± 0.4	4.5 ± 0.3	4.7 ± 0.4	0.24
10. Estimated weight of fat	(kg)	11.5 ± 1.8	15.6 ± 1.3	16.3 ± 1.1	17.3 ± 1.4	0.31
11. Weight	(kg)	73.3 ± 2.5	76.3 ± 1.9	78.1 ± 1.6	77.1 ± 1.9	0.18 [2]
12. Height	(cm)	176.5 ± 1.0	177.4 ± 1.8	177.3 ± 1.0	175.3 ± 1.9	—

[1] Mean ± s. e.

[2] Not significant.

Inasmuch as the age "changes" detailed here are primarily changes in fat-containing tissue and weight, they are best illustrated by showing the relationships between the estimated weight of fat, and the 9 subcutaneous fat thicknesses (table 2). As also shown in figure 1, all of the fat thicknesses rise with the estimated weight of fat, including the anterior leg fat, a trend which has been verified separately. Iliac, trochanteric and deltoid-insertion fat form one cluster of lines while the

distal fat thicknesses form a second cluster. The "crossing over" of iliac and deltoid-insertion fat is clearly shown. What is especially evident in figure 1 is the fact that the accumulation of fat with age follows the general fat-weight, fat-thickness trends, and that older men of average weight for age have the surface contours that would be expected for younger men 0.5 standard deviation or 5 kg (7%) "overweight" for their age.

TABLE 2

Relationship between fat and weight changes

Measurement	Mean thickness (mm)	Weight change (kg) per mm fat [1]	Fat change [2] (mm) per kg weight
1. Deltoid insertion fat	17.8	1.35	0.74
2. Lateral arm fat	4.6	3.32	0.30
3. Medial arm fat	3.5	3.15	0.32
4. Iliac fat	18.9	0.69	1.45
5. Trochanteric fat	16.6	0.94	1.06
6. Posterior leg fat	7.2	1.49	0.67
7. Anterior leg fat	2.7	7.93	0.13
8. Medial leg fat	6.3	2.69	0.37
9. Lateral leg fat	4.7	1.64	0.61

[1] Calculated from formula $y = r\frac{\sigma y}{\sigma x}x$ using values given in Garn ('54). The actual age-associated changes in fat closely follow the predicted values, as shown in figure 1.

[2] Calculated from column 2.

Under these circumstances, then, "ageing" in the male, within the limits set by this study and the age span considered, closely corresponds to ordinary fattening. The surface contours of the average older man bear a marked resemblance to the surface contours of the fatter younger man, being greatest about the hips, at the trochanteric region, and on the upper arm. Less evident to the eye, but equally important, fat is added peripherally, but at a lesser rate, and to layers initially thinner.

DISCUSSION

It is evident, from the preceding findings, that ageing in the male, or more precisely, the simple passage of time, is accompanied by an

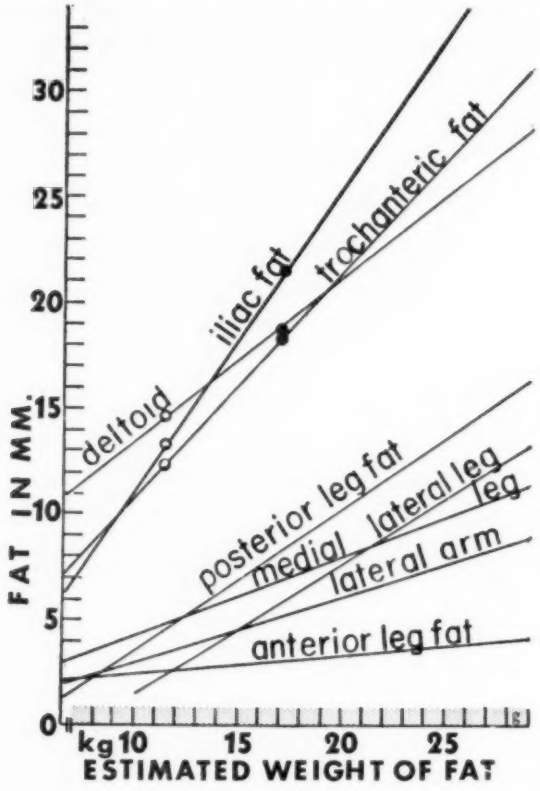

FIG. 1.

Relationships between the estimated weight of fat (abcissa) and the thickness of the subcutaneous fat (ordinate) as derived from data on adult males weighing 58 to 94 kg. Note the tendency for the regression lines to form two clusters, and the crossing over of deltoid and iliac subcutaneous fat. The open circles, representing means for the 20-30 age groups, and the closed circles representing the 50 to 60 age groups, show that the age-accumulation of subcutaneous fat follows the general fat-thickness, fat-weight trend. Therefore it is assumed that the age changes closely resemble simple fattening.

increase in the thickness of fat-containing tissue over the entire body, with the largest absolute gains over the pelvic girdle. Quantitatively

the increases over a three-decade period range from negligible values to nearly 8 mm, depending on the part considered. Percentagewise, subcutaneous fat gains range up to 58%, with an average increase of 30% for the 9 fat measurements. In a rough way, there is a division between centrally-deposited fat (which adds at a rate approximating 1 mm per kilogram of weight or fat gained) and peripheral fat, which accumulates at a much slower pace (*cf.* Škerlj *et al.*, '53). The simplicity of this dichotomy is marred by the deltoid-insertion fat, however, and by the markedly different rates of fat accumulation on the 4 quadrants of the lower leg.

In these active white males, the bulk of the increase in weight and subcutaneous fat takes place early, being largely completed by the end of the fourth decade. This parallels the disproportionate early weight gain observed in male coronary heart disease patients and controls (Garn, Gertler, Levine and White, '51), a trend also observable in the U. S. Army 40-105 age-weight norms (Levy *et al.*, '46, p. 952) in Davenport's 1923 summary, and in the Irish data of Hooton and Dupertuis ('52, p. 9). Brožek ('52, p. 787) comments on a similar trend in percentage fat during the same age span, and suggests a parabolic equation as the best fit. However, earlier data, such as Quetelet's (reprinted by Thompson, '44) seem to show a much earlier termination of the period of weight gain, and therefore the question of the type of equation may be left open.

Why fat is gained after osseous maturity is far from clear, although this pattern holds both for man and his domestic animals as well (Clarke and McMeekan, '52; Barnicoat and Shorland, '52). In discussing the greater fat content of ewe and wether carcasses, in comparison to lamb carcasses, Clark and McMeekan generalize as follows: "It is clear that the changes with weight are in accord with our knowledge of the laws of differential growth in the animal body. Bone, as the earliest developing tissue, shows the least increase, fat as the latest developing tissue, the greatest increase."

While part of the adult fat gain noted here and in similar studies may well have a developmental basis, current opinion relative to man stresses the nutritional aspect. This is not simply a matter of increased caloric intake, for fat storage may be speeded by a decrease in energy expenditure as well. Thus, the appetite in the pre-adult male and in the young adult may be physiologically determined, but as appetite becomes a matter of habit rather than need, and as voluntary activity

declines, the excess of caloric intake over caloric expenditure leads to the accumulation of fat. In terms of the present material, voluntary activity may decline during the third and fourth decades, becoming more nearly stable thereafter.

But the changes in body composition observed here and in the publications of the Minnesota group (see Brožek, '53 for bibliography) represent changes during a life phase marked by a decreasing hormonal output. From the third decade on, the excretion of urinary 17 ketosteroids is on the decline (Hamilton, '47; Pincus *et al.*, '54). This is true of the 3 and 20 ketosteroids as well, and may be true of the 11 ketosteroids (Clark and Garn, '54b). In a slow way, this gradual falling-off parallels the abrupt changes following castration, with creatinuria, loss of muscle, decreased basal oxygen consumption, and a usual but not invariable increase in fat (Hamilton, '47). Notably, certain steroids have a direct effect on fat metabolism, rapidly decreasing stored fat in castrate animals (Kochakian, '46). And the urinary ketosteroids in the human male appear to contain a substance directly related to energy metabolism (Clark and Garn, '54a). All of these facts lend credence to the possibility that the age-associated increase in fat in the male is in part related to the decrease in hormonal output. This relationship may be direct, involving some degree of hormonal control of fat deposits, or it may be indirect, operating through a decreased energy expenditure.

While there is no doubt that fat is gained during this age span, as can be demonstrated in a variety of ways, it would be a mistake to consider the acquisition as merely a gain in saponifiable fatty acids. More precisely, what is gained is *fat-containing tissue*. This is especially important in studies measuring the thickness of the fat shadow on skiagrams, such as the present one, and where skin-fold thicknesses are measured, for fat-containing tissue also includes connective tissue, a vascular network and water (*cf.* Barnicoat and Shorland, '52). And, while the specific-gravity technique more nearly approaches the measurement of pure fat, the specific gravity of the tissues lost on a weight-reducing regime exceeds the specific gravity of pure fat (Behnke, '53, personal communication; Keys and Brožek, '53, p. 292).

A further complication is offered by the fact that fat itself is not a chemical constant. Neglecting brown fat, which occurs only during embryonic life in man (Wertheimer and Shapiro, '48) there is a notable change in the chemical composition of the fat as age progresses.

This involves a replacement of "soft" fat, with its higher proportion of unsaturated fatty acids, by "hard" fat, with its greater proportion of saturated fatty acids (Barnicoat and Shorland, '52). Hence, the increase in fat-containing tissue observed in this study may be paralleled by a change in the composition of the fat as well. And further, it must be noted that fat in different parts of the body contains markedly different amounts of vitamin E (Quaife and Dju, '49; Quaife, Swanson, Dju and Harris, '49) so that the total amount of alpha tocopherol stored in the body depends both on the amount of fat and the location of the fat. There is a suggestion here that particular patterns of fat deposition may prove to be physiologically meaningful rather than just the actions of a capricious Nature.

Recognizing then that we are concerned with fat-containing tissue, variable in its fat content, in the chemical composition of the fat it contains, and in the substances dissolved in the fat, it is still possible to deal with the variations in the *tela adiposa* as a prime variable in morphological patterning. The different rates at which fat deposits on separate parts of the body make intelligible the changes in surface conformations that may be observed with advancing years and, equally, the different outlines of men, fat and thin. We may predict, from a knowledge of the fat content, the thickness of the fatty tissue on different parts of the body. We may draw grid transformations illustrating the changed outlines that follow changes in the body fat.

SUMMARY

1. The thickness of the subcutaneous fat-containing layer at 9 sites was measured on soft-tissue teleoroentgenograms of 85 males aged 20 to 69 years
2. Eight of the 9 thicknesses showed age-associated increases with an average increase over 4 decades of 30%.
3. The maximum increase was exhibited by iliac fat, being 7.8 mm (58%).
4. Iliac, trochanteric and deltoid-insertion fat were initially thicker and increased more than fat on the lower arm and leg.
5. The weight of fat, as estimated from trochanteric fat, increased from 11.5 to 17.3 kg and estimated percentage fat rose from 16% to 22%, paralleling the rise in weight.

6. Both fat and weight increases were more marked during the third and fourth decades, as seems to be characteristic of other recent data on white males.
7. As shown on fat-thickness, fat-weight curves, changes in surface contours resemble simple fattening.
8. Attention was directed to the fact that these increases in fat-containing tissue involve significant additions to non-fatty components and changes in the chemical composition of the fat.
9. The fact that fat increases while the level of excreted ketosteroids decreases suggests either possible hormonal mediation or indirect mediation through decreased voluntary activity.
10. The simple relationships existing between the estimated weight of fat and the 9 fat thicknesses suggest an approach to one aspect of body form.

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BOOK REVIEWS

Modern Learning Theory. By W. K. Estes, S. Koch, K. MacCorquodale, P. E. Meehl, C. G. Mueller, Jr., W. N. Schoenfeld, W. S. Verplanck. Ed. by A. T. Poffenberger. xv + 379 pp. Appleton Century-Crofts, Inc., N. Y. 1954. $5.00.

This is a review of the handiwork of seven reviewers who examined the work of 5 psychologists considered to occupy a prominent position in the field of learning. Hull gets 177 pages, Tolman 90, Skinner 56, Lewin 28, Guthrie 32.

We are led over hill and dale of the Hullian system by Koch who concedes that "we have done what may be construed as a very nasty thing." He concludes that Hull "failed not merely because he aimed at comprehensive theory, or because relevant empirical knowledge is too painfully slim to justify even far more limited attempts" but "because he did not adequately meet concrete problems of *empirical definition, of measurement, of quantification, of intervening variable function construction,* and various sub-specifications of all of these." We wonder, though, why it took Professor Koch nearly one-half of the book to come to this conclusion.

Next Tolman is taken for a ride by Professors MacCorquodale and Meehl, ending with an "Apology to Tolmanites and Others" and the statement: "In its main outlines, we have seen no reason to criticize Tolman's approach as a *knid* of behavioral theory. Like its other critics, we wonder at its lack of even a minimal amount of formalization over the 20 years of controversy and experiment."

It is a relief in the next two chapters dealing with Skinner and Lewin to be through with "apologies" and to hear some straightforward simple talk. Together these two authors take up on 20% of the book, but contribute most of the sense. Verplanck says: He [Skinner] wishes to find out how animals behave and seeks a vocabulary that will let him talk about how they behave. Because of the existence in Sherrington and Pavlov of sets of data of the kind he believes are needed, he has adopted many of their terms and applied some of their laws in defining his area." A good comparison is made of Skinner, Tolman and Hull. Skinner makes good sense and is head and shoulders above the others.

Estes in 27 pages gives us an equally lucid analysis of Lewin's

concepts. The fallacies of the popular "field theory" are revealed. "None of the so-called field theories have been developed in conjunction with programs of experimental research upon learning. Typically the field theorists have developed their systems in other areas, then have attempted to collect the psychology of learning as an extra dividend without much additional investment."

Under the pens of Mueller and Schoenfeld, Guthrie emerges as a pygmy strutting among the concepts of the more illustrious folk in psychology (Pavlov, Thorndike, Lashley).

Stimulated by the abstruse formulation and the elaborate diagramatics of the first two chapters, I made a simple statistical survey of the references in the bibliographies of the 5 reviewers. To the great figures in the history of learning and psychology, or those that I consider prominent, *viz.*, James, Pavlov, Bechterev, Thorndike, Watson, and Koehler, there are no references with the exception of one to Pavlov by Verplanck and one to Koehler by Estes. This seems to me some criterion of the scope of the reviews.

The book will undoubtedly appeal to the academic psychologist who wants to have a thorough digest of these 5 contemporary authors of learning theory, but it will not satisfy the general reader who is looking for a broad and scholarly discussion.

W. Horsley Gantt

BOOKS RECEIVED

NEEDED RESEARCH IN HEALTH AND MEDICAL CARE: A BIO-SOCIAL APPROACH. By Cecil G. Sheps and Eugene H. Taylor. ix + 216 pp. University of North Carolina Press, Chapel Hill, N. C. 1954. $5.00.

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